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Theoretical Prospects for Orbiting VLBI

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Final Report

Induced Compton Scattering

Blandford completed a collaboration with Coppi (Chicago) and Rees (Cambridge) on induced Compton scattering. A series of simulations were performed to show the (strong) influence of anisotropy and source inhomogeneity on the observed effects of induced scattering. Induced Compton scattering occurs when high brightness transverse electromagnetic waves are scattered by free electrons. The scattering rate is enhanced above the spontaneous rate by the high occupation number of the scattered state. Taking into account electron recoil, it is found induced scattering is important when the brightness temperature exceeds $\sim m_e c^2/k$. Various physical effects including an increase in source brightness temperature, limb brightening, linear polarisation and superluminal expansion were all exhibited. Specific predictions for future VLBI observations using both the VLBA and orbiting VLBI. In particular, it is predicted the longest baselines to be probed are predicted to show no fringes from compact quasars. A paper has appeared.

Stimulated Raman Scattering

Thompson (CITA), Blandford, Evans (North Carolina) and Phinney (Caltech) carried out an extended analysis of plasma processes likely to be important in eclipsng radio pulsars. Appendix B of this paper contains a lengthy and original analysis of stimulated Raman scattering, elucidating its connection to induced Compton scattering. Stimulated Raman scattering is an induced process in which there is scattering between two transverse electromagnetic wave states with the creation or annihilation of longitudinal plasmons. They were able to show how to treat this process when the electromagnetic waves are broad band and the plasmons are damped. This is of direct relevance to AGN. Blandford and Levinson have completed numerical simulations of non-linear radiative transfer of high brightness radio emission including the damping and escape of Langmuir waves. The principle conclusion is that, as with induced Compton scattering, there is no evidence in the observations that this process is at work in AGN. This sets upper bounds on the source brightness temperatures granted reasonable assumptions about the free electron density surrounding the source and rules out explanations of intraday variability based on coherent emission processes. The incidence of intraday variability and high direct brightness temperature measurements using orbiting VLBI places even stronger constraints on the source conditions than can be set from the absence of induced Compton scattering. A paper is in press.

γ-ray Jets

Compton GRO observations of core-dominated compact radio sources show variable, intense γ-ray emission, presumably originating from the same jets that are responsible for the expanding radio features. The γ-ray emission is found to arise at smaller jet radii and so can be used to constrain the radio structure to be expected when these sources

are observed with the superior resolution of orbiting VLBI. Blandford introduced a model for the jet emission in which the γ-rays are formed by an electron-positron pair cascade, powered by Poynting flux originating from a spinning massive black hole. The soft photons were deemed to be soft X-rays from the inner accretion disk Thomson scattered into the path of the jet by free electrons in the accreting plasma. Blandford & Levinson performed a more careful analysis of this model and showed that it could account for the observations of γ-rays as well as accommodate a unified model of AGN. Levinson and Blandford then went to explain how X-ray emission could be explained within this scheme. In particular they associated the hard X-ray turnover, seen primarily in Seyfert galaxies with the break in the γ-ray spectrum. They also associate these two energies with the characteristic bulk Lorentz factors of relativistic jets, $\Gamma \sim 10$. Two papers are in press and two more are in preparation.

3C84

Levinson, Laor & Vermeulen have analyzed recent VLBI observations of 3C84. They argue that the counter-jet is subject to free-free absorption at low frequency and argue that the absorbing plasma must be photoionised. They explain th eobserved [OIII] flux and predict that it will be unresolved by HST.

Particle Acceleration

Levinson has completed a study of electron injection and acceleration at non-linear shock fronts of the sort that are believed to be present in active galactic nuclei. The electrons are believed to be injected by self-generated whistler waves and the e-p ratio in non-relativistic shocks is computed to be 1-10 percent in rough accord with Galactic cosmic ray studies. The extension of these ideas to faster, mildly relativistic shocks is currently being explored. A paper has appeared.

Electron-positron fireballs

Levinson and Eichler have completed an analysis of electron-positron fireballs. Although intended for application to cosmological models of γ-ray bursts, this is quite relevant to the physics of the jets observed in AGN.

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Levinson, A., Laor, A. & Vermeulen, R. C. 1995 Constraints on the Parsec-Scale Environment in NGC 1275 ApJ in press
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